Permeable Pavements in Cold Climates: Lessons Learned from Practice and Research

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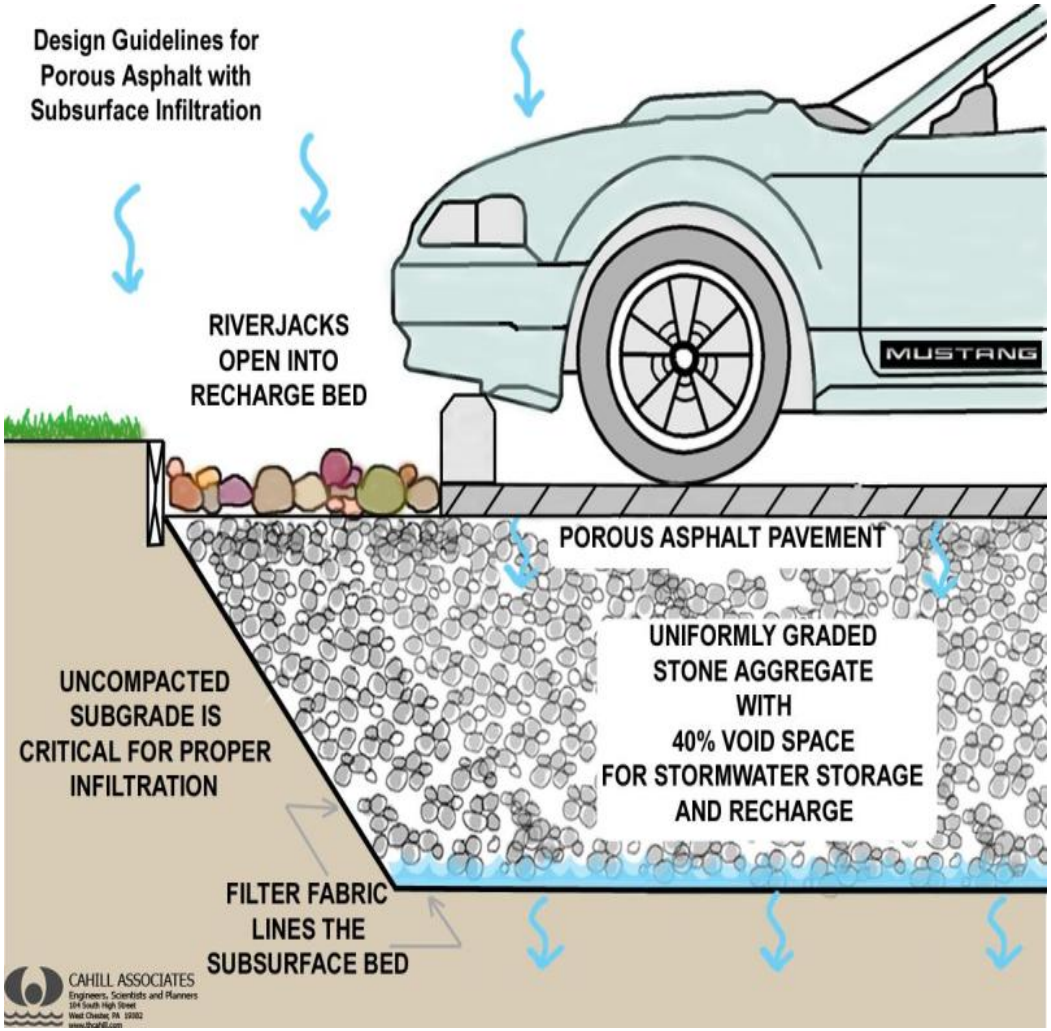
Porous pavements developed as early as the 1930s

A sign at a park in Massachusetts. Image source: MAAPA

Full Depth Permeable Pavement X-Section

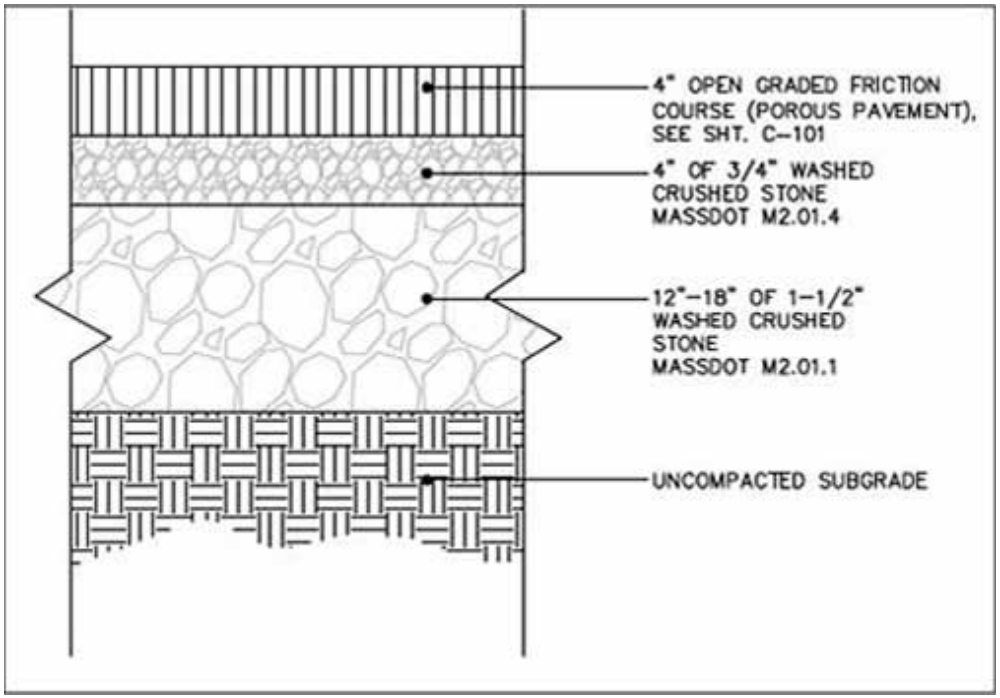


- Water infiltrates through permeable pavement surface and other layers
- Stored in gravel layer (~40% voids)
- Water infiltrates into soil or is collected by drain tile

Image: CAHILL Associates 2003

Project Scope

- Full depth permeable pavement:
  - Literature review
    - Structural design
    - Hydrologic design/performance
    - Water quality impact
    - Maintenance requirements
  - Cold climate case studies
  - Research needs
  - Software to determine feasibility of permeable pavement



- Does not include permeable friction course

Image: www.epa.gov

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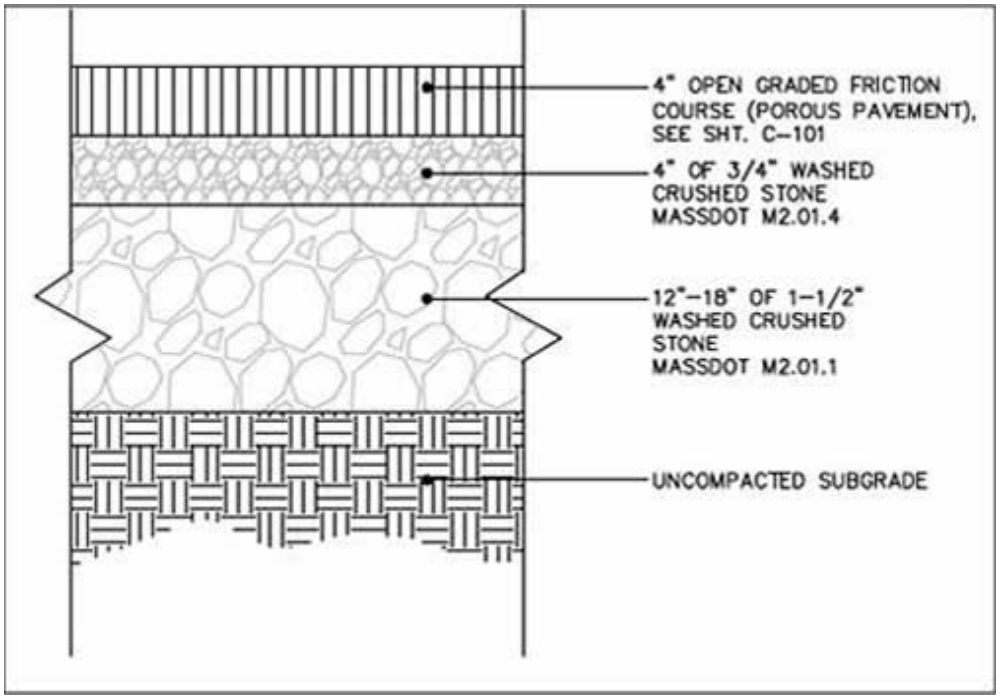

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Benefits of Permeable Pavement

- Volume Reduction
- Improved water quality
- Hydroplaning resistance
- Spray reduction
  - Increased visibility
- Smoother riding surface
- Noise reduction
- Less winter salt application


Impermeable pavement


Permeable Pavement

Photos: Barrett 2008

Permeable Pavement Types

- Porous Asphalt
- Pervious Concrete
- Permeable Pavers
- Permeable Articulated Concrete Blocks

Keys for Success

- Proper Construction
  - Mix design
  - Compaction
  - Void ratio
  - Curing
- Proper & regular maintenance

Photo courtesy of M. Maloney, Shoreview, MN

Summary of Hydraulic Performance

- Surface infiltration rates decrease but are not rate limiting
- Method needed to determine permeability of sub-base before design
- Geotextile fabrics can reduce/eliminate infiltration
- Infiltration rates are maintained through winter

Photo http://ih.constantcontact.com/

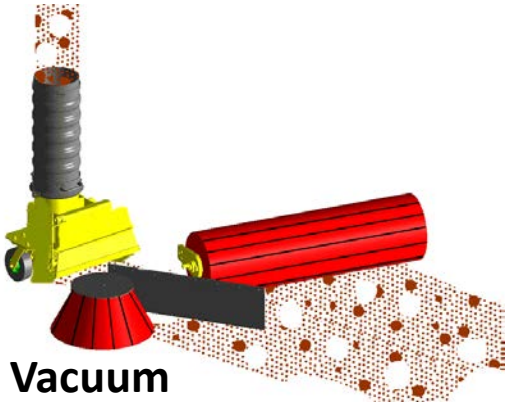
Summary of Water Quality Impact

- Removes solids & solid-bound contaminants
- Mass load reduction often through infiltration
- Nitrification may occur (ammonium to nitrate), but total N removal is low
- Dissolved phosphorus removal is minimal

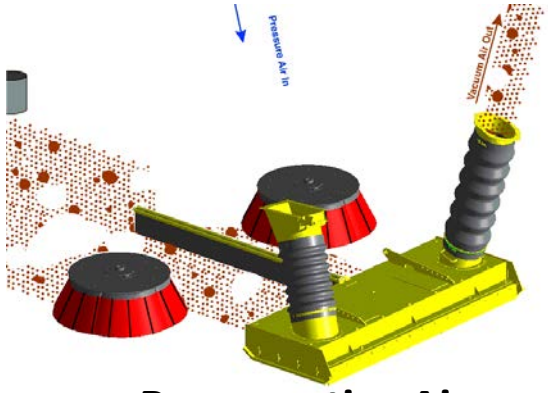
Photo http://switchboard.nrdc.org/

Summary of Maintenance

- Surface cleaning is effective but variable
- Particle removal (top ¼ inch) is major issue
- Pressure washing (45^{o}) and/or vacuuming with regenerative air sweepers is most effective
- Brushes can push material farther into voids
- Clean multiple times per year



Vacuum

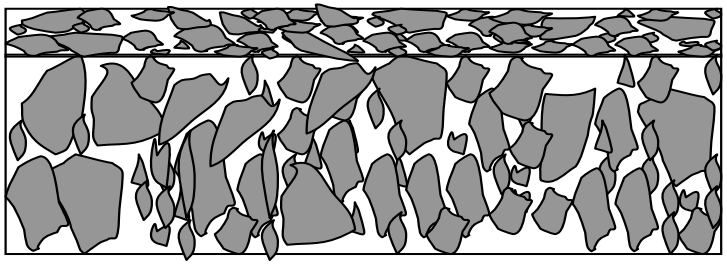


Regenerative Air

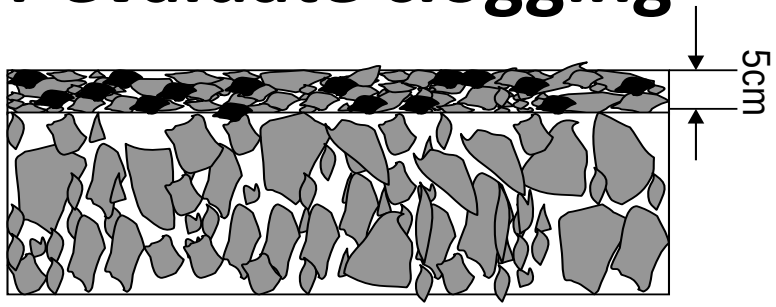
Images: Elginsweeper.com

Summary of Maintenance

- **Major cause of clogging is reduction of surface pavement void space:**
  - **Heavy loads**
  - **Particles**
  - **Lack of maintenance**
- **No standard to measure or evaluate clogging**



Open voids



Partially clogged voids

Impact of Vacuuming

Permeable articulated concrete blocks/mats before (A) and after (B) cleaning with a Vac Head.

(Photo courtesy of University of Louisville and D. Buch, PaveDrain, LLC).

Porous Asphalt Paired Intersections - Robbinsdale

Constructed 2009-2010

Construction in September 2010 (Wenck 2014)

Paired Intersection Study

- Objective was to evaluate possible reductions in salt loads on porous asphalt pavements
- Also durability, maintenance, and water quality

Paired Intersection Study

- Two porous asphalt pavement intersection were constructed: one over a sand sub-base and the other over a clay sub-base.
- Designed to store the 2-yr storm
- Each porous asphalt section was approximately 150 feet long and 28 feet wide for a total area of about 4200 square feet.
- The porous asphalt sections were not salted during the winter.
- Conventional asphalt sections were salted.

(thenewsherald.com)

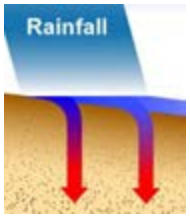
Paired Intersection Study

Results

- Reservoir temperatures in both PP systems during winter was consistently warmer than the pavement temperature

- Attributed to the air within the voids of the reservoir layer insulating the reservoir

- Insulation minimizes winter freezing and keeps reservoir temperatures cooler in spring



- Suggests winter infiltration into subgrade is possible

Paired Intersection Study

Results

- Conventional pavement sites were slushier than the porous asphalt sites due to infiltration into PP

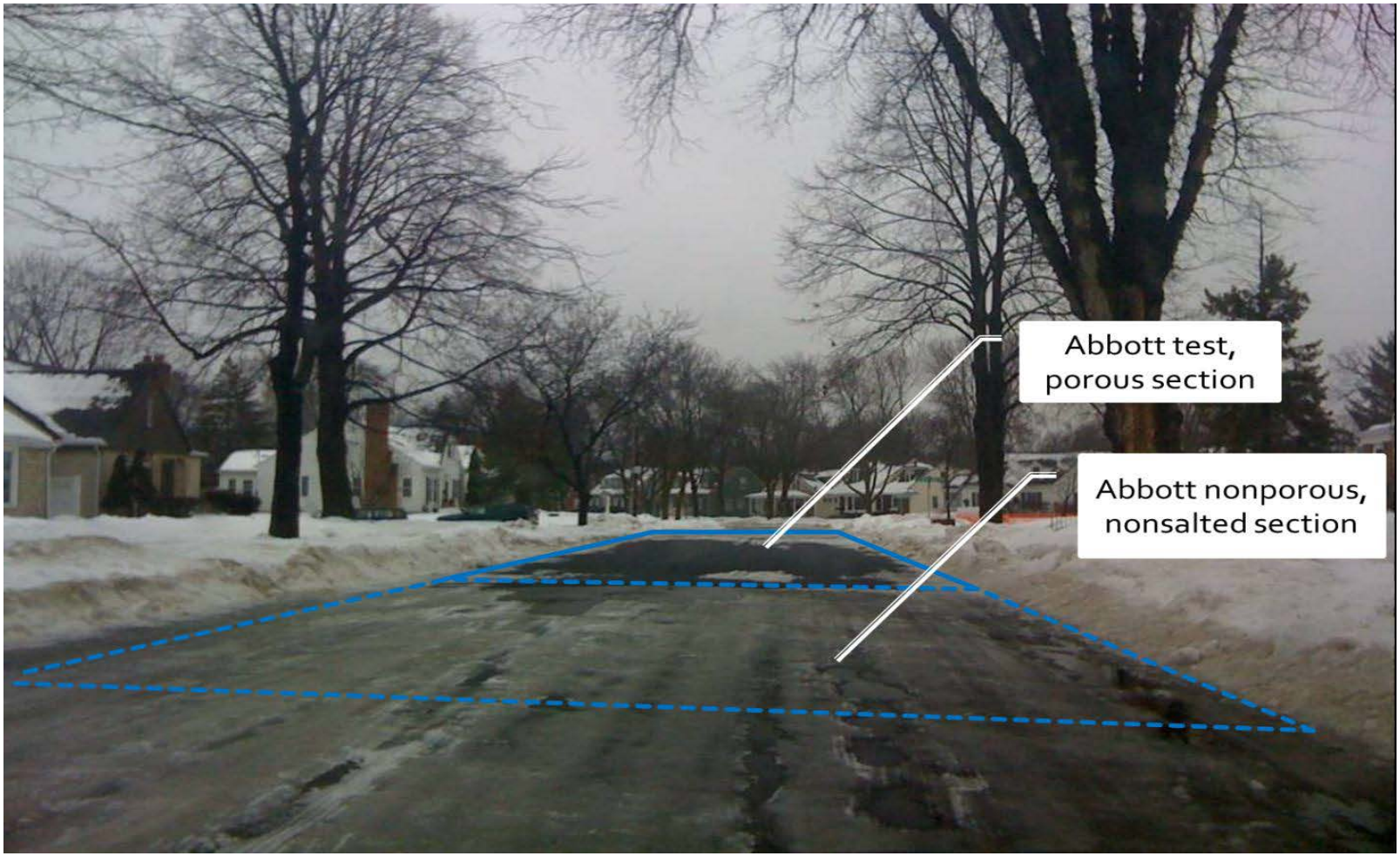
- Bare pavement on the porous test sections was comparable to that on conventional asphalt sections but had a lag of 2 to several hours

Paired Intersection Study

Slush gathering and refreezing on the traditional asphalt at Site 1 on January 17, 2010

Slush free porous asphalt on January 17, 2010

Paired Intersection Study



Site 1 Test Section looking south

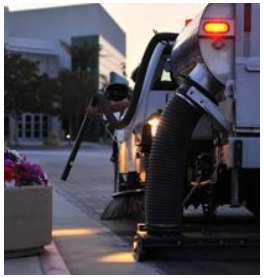
Paired Intersection Study

Lessons Learned

- The unsalted, porous asphalt sections had a similar amount of bare pavement compared to salted, conventional asphalt sections
- The porous pavement over sand subgrade was more effective for ice control compared to the porous pavement on clay subgrade
- Porous asphalt sections have been durable without any special snow plow equipment or adjustments

Paired Intersection Study

Lessons Learned



- Effective maintenance on the porous asphalt sections appears to be vacuuming (regenerative) twice per year and patching with traditional asphalt, as necessary
- Porous asphalt intersections have potential as an ice-control management practice in certain situations

Woodbridge Neighborhood-Shoreview, MN

Pervious Concrete, constructed in 2009.

Photo courtesy of M. Maloney

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Woodbridge Neighborhood

Initially:

- **38 ac, fully developed**
- **9000 yd^2 of asphalt**
- **Storm drainage concerns**

Needed to:

- **Replace road, upgrade utility, improve stormwater management**
- **Total cost = $15M**

Photo courtesy of M. Maloney

Woodbridge Neighborhood

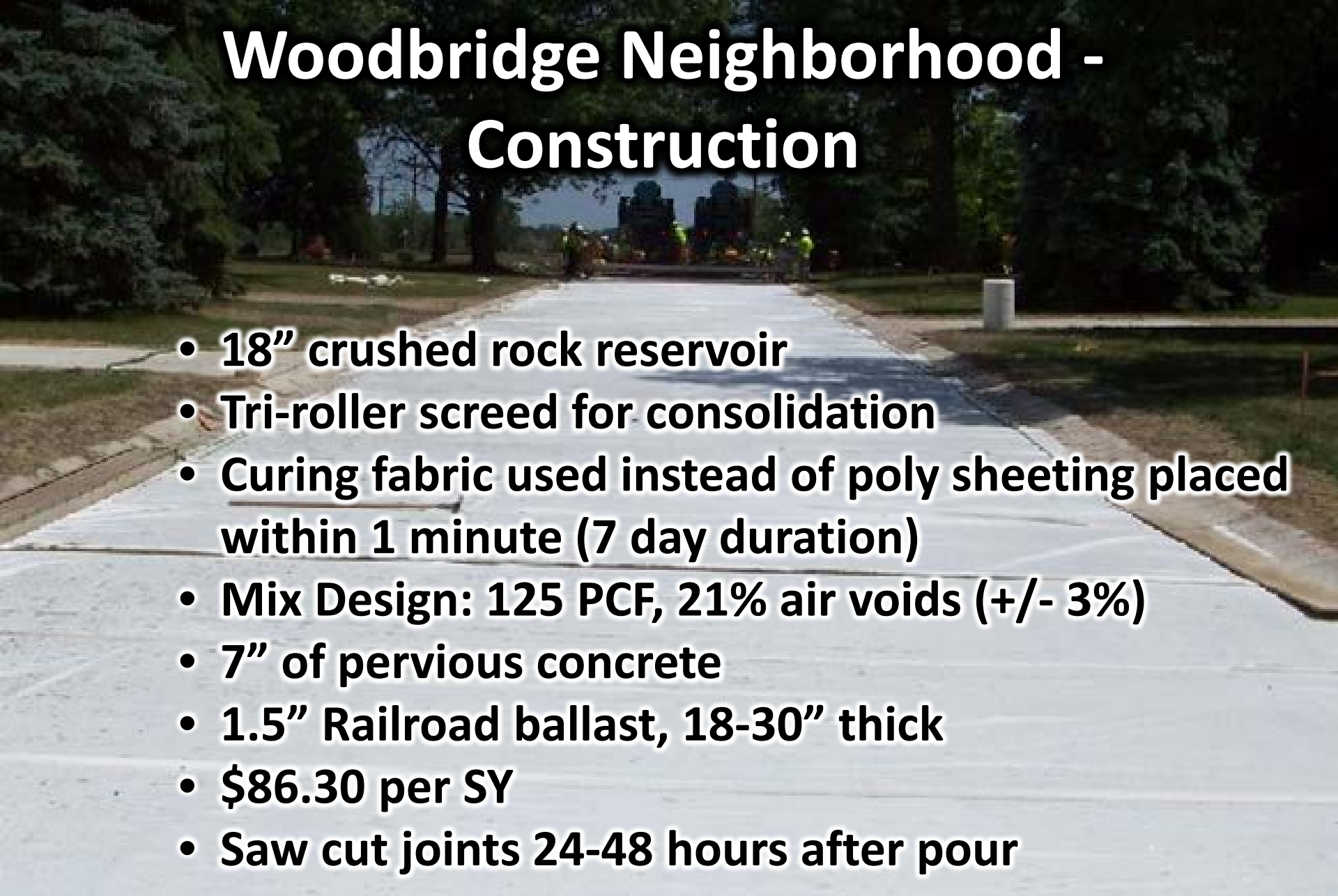
Why PC?

- **Free draining soils**
- **Advances in mix designs and placement techniques**
- **Same cost as conventional asphalt with storm drains**

Project construction.

Photo courtesy of M. Maloney

Woodbridge Neighborhood - Construction



- 18” crushed rock reservoir
- Tri-roller screed for consolidation
- Curing fabric used instead of poly sheeting placed within 1 minute (7 day duration)
- Mix Design: 125 PCF, 21% air voids (+/- 3%)
- 7” of pervious concrete
- 1.5” Railroad ballast, 18-30” thick
- $86.30 per SY
- Saw cut joints 24-48 hours after pour

Curing of Pervious Concrete.

Photo courtesy of M. Maloney

Woodbridge Neighborhood - Maintenance

- Regenerative air sweeper (no brushes); ~ every 6 weeks
- No salt or sand application
- Plowed by one-ton pickup w/ regular plow
- Clogging occurs mostly in top ¼” of pavement
- Maintenance has maintained infiltration rates of 300-500 in/hr in most areas

Photo courtesy of M. Maloney

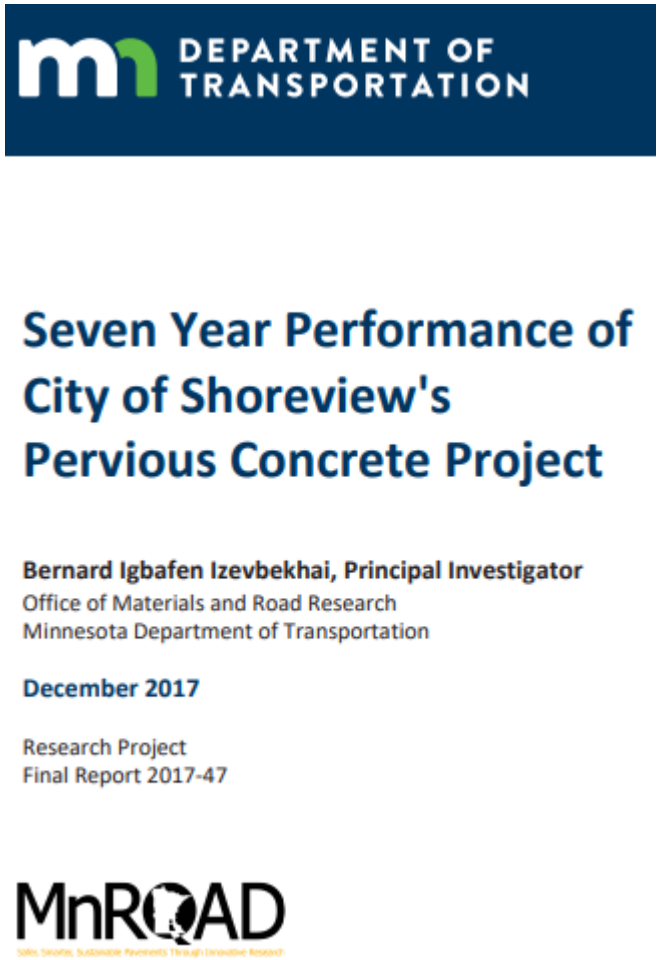
Lessons Learned

- Construction & curing very important
- Saturated curing blankets have been successful
- Saw cut joints have been successful
- Snow plowed with regular plow
- Maintenance is effective

Image: Saw cut joint.
Photo courtesy of M. Maloney

Woodbridge Neighborhood

MnDOT Study & Report



- After 5 years, 20% of traverse joints were spalled & 15% surface raveled
- Deicing salt section most raveled
- Hydraulic conductivity is decreasing but still at functional level
- Sound adsorption is decreasing
- Including maintenance costs and anticipated surface grinding, pervious concrete is more cost effective than alternatives

For more info see:
http://dotapp7.dot.state.mn.us/projectPages/pages/projectDetails.jsf?id=42019&type=DOCUMENT

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The Denver (UDFCD) Experience

Denver, Colorado.

Photo: PlaneandJane.com

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Denver Safeway Parking Lot

- Pervious Concrete
- Installed in 2004
- No info on mix design
- Surface erosion

Photo courtesy of K. MacKenzie, UDFCD

Denver Waste Management Building

- **Cores revealed proper construction (17% voids, proper PSD, asphalt content, etc.)**
- **More than half of other PA sites have infiltration < 20 in/hr**
- **UDFCD does not recommend use of PA**

Parking lot after snowfall. Photo courtesy of K. MacKenzie, UDFCD

Overall Conclusions

- **Permeable pavements can result in less winter salt application**
- **Permeable pavements can reduce runoff volume and improve water quality (with other benefits)**
- **Permeable pavements are more expensive to construct**
- **Construction & maintenance are critical to success**

Overall Conclusions (Cont'd)

- **Maintenance: pressure washing and/or vacuuming**
- **Permeable pavements can withstand harsh winters**
- **Permeable pavements can maintain infiltration rates throughout the winter**
- **Advances are being made continuously**


Thank you for your attention!
Questions?
Peter.Weiss@valpo.edu
http://itcontrolsfreak.files.wordpress.com/2012/11/rain1.jpg

Research Needs

- Structural/Construction: long-term performance, aggregate grading, geotextiles, compaction energy, in-situ tests, life-cycle cost analysis…
- Hydraulic/WQ: mix design as pollution source, hydraulics w/ heavy loads, raised drain tile, long-term WQ, N/P fate..
- Maintenance: quantify clogging, cleaning methods, frequency, optimal pavement design…